SECTION 4.0
SURFACE EROSION ASSESSMENT

4.1 INTRODUCTION

This analysis of surface erosion was performed in accordance with the methodology outlined in the surface erosion module of the manual (WFPB 1994). The assessment of surface erosion from hillslopes (Section 4.2) is documented separately from road surface erosion (Section 4.3).

4.2 HILLSLOPE SURFACE EROSION

4.2.1 Soil Erodibility

Soils within the Acme WAU are mapped in the Whatcom County Soil Survey (SCS, 1992). Figure 4-1 is taken from the general soil map within this survey. There are eight general map units within the Acme WAU, each composed of several specific soil map units. The more inclusive general map units are sufficient for the purposes of this assessment, and hence, individual soil units will not be addressed.

The eight general map units within the Acme WAU can be grouped further into categories of similar geomorphic origin. General map units #1, Mt. Vernon-Puyallup (light green), and general map unit #3, Briscot-Oridia (yellow), compose the flood plain and deltas of the South Fork Nooksack River and its lowland tributaries (Figure 4-1). These soils are very deep and may be very poorly drained or well drained. Parent material of these soils is the alluvium from the South Fork Nooksack River and its tributaries. General map units #4, Kickerville-Barneston-Everett (salmon), occurs within glacial outwash, as is visible along the North Fork Nooksack River on the northern boundary of the WAU, and moraine or till southwest of the town of Acme. These soils are deep to very deep and of highly variable drainage. Most of the poorly drained areas have been drained artificially. General map unit #10, Van Zandt-Squires, (yellow) occurs on the foothills of the southern portion of the Van Zandt Dike. These soils are moderately deep to very deep and are moderately well drained to very well drained. General map units #12, Montborne-Rinker (purple), and #13, Oakes-Revel (pink) comprise the upland portion of the Van Zandt Dike, and the southern highland area of Burnt Ridge. These soils are moderately to very deep and well drained. Parent material of soils in general map unit #13 is the Chuckanut sandstone formation, and parent material of unit #12 is the pre-Tertiary metamorphic phyllite (see Chapter 3, mass wasting for further geologic description). General map units #14, Getchell-Kindy-Potchub (green), and #17, Rock Outcrop-Typic Cryorthods-Andic Cryochrepts (aqua) are located along the peaks of Burnt Ridge, north of the Chuckanut - phyllite contact. These soils are moderately to very deep, and well drained.

Erosion hazard of the individual soil map units are addressed also in the soil survey. Ratings of erosion hazard provide a rough categorization of the probability that damage will occur as a result of site preparation and harvesting where the soil is exposed along roads, skid trails, and other management-induced disturbed areas (SCS, 1992). The erosion hazard ratings, Slight, Moderate, or Severe, are closely correlated with the

Table 4-1 Erosion Hazard Ratings of the General Map Units in the Acme WAU. (from SCS, 1992)

Soil General Map Unit #	Typical Erosion Hazard Ratings
1	slight
3	slight
4	slight or moderate
10	slight or moderate
12	moderate
13	slight or moderate
14	slight or moderate
17	severe

local hillslope gradient. Erosion hazard ratings for the eight general map units in the Acme WAU are shown below in Table 4-1.

Hillslope gradient of the soil series can be inferred from Table 4-1. The lowland soils of least hillslope gradient have ratings of slight to moderate. The steepest gradient areas are rated severe. It appears that differences in erodibility of the soil units independent of hillslope gradient were thought to be negligible.

4.2.2 Contributing Activities

Most broad scale land management activities in the Acme WAU fall within two broad categories: timber management, and agriculture. Construction and other related impacts of residential use occur in a more scattered distribution. Timber harvesting and related management activities occur on roughly 60% of the land within the Acme WAU. The watershed analysis methodology, and hence this assessment, is oriented toward forested lands, and their uses. The investigation of the effects of timber harvesting on surface erosion consisted of remote reconnaissance and field inspection at six sites within the Acme WAU. The remote reconnaissance involved perusal of the 1987 and 1991 aerial photographs to locate any evidence of erosion and sediment delivery to streams, and to aid in mapping recent harvest units (shown in Figure 4-2). The field inspections involved on-site investigations of ground disturbance within recent harvest units. Site locations are shown in Figure 4-2 and are discussed in Section 4.2.3.

Recent harvest units shown in Figure 4-2 are those units that were present on the 1991 aerial photos, but were not present on the 1987 photos. Therefore, the units shown were harvested between July of 1987 and August of 1991. By 1994, they ranged in age from approximately 3.5 years to 8 years. Nearly all the harvesting during this period was in the form of clearcutting (shown as red on Figure 4-2). Two small areas of partial cuts were noted (shown as black cross-hatches). The eastern boundary of one clearcut (located in Section 12, T 37 N, R 4 E) was not identified due to a missing photo. Harvesting during this period was scattered through most upland areas of the WAU with the exception of Sygitowicz and Hardscrabble basins in the west, and in the vicinity of Devil's Slide in the east. Hillslope gradients on which harvesting occurred ranged from flat to 100% (approximately), if locally steep portions of inner gorges are considered. The most extensive logging practice has been cable yarding. Evidence of numerous cable corridors and landings are visible across the landscape.

Approximately 40% of the Acme WAU consists of agricultural lands on the floodplain of the South Fork Nooksack River. Grazing and haying are prevalent uses, with smaller areas utilized for Christmas trees and other crops.

Erosion from land clearing and construction projects can generate sediment locally and in some cases, may deliver considerable fine sediment to streams. Evaluating such contributions, which are generally short-term and dispersed throughout the lowland areas, was not feasible within this project.

4.2.3 Erosion and Delivery

Field inspections were conducted at six clearcut sites (Table 4-2) to observe evidence of ground disturbance from timber harvesting activities.

Site 1, located north of Turkington Road in the town of Acme, was the only site that was not located in a recent harvest unit. No harvest units exist on the floodplain, so the investigation was conducted at a site representative of the floodplain. Site 1 was nearly completely vegetated with various types of grasses. No erosion was observed. Sites 2 through 6 are in recent harvest units. Hillslope gradients ranged from 20% to 75%. Rills were observed in compacted areas (skid trails) at all but Site #2 Sheetwash was evident at these sites also, between clumps of vegetation. Slash and a duff layer were present at all the harvested sites. Both of these reduce the incidence of surface erosion by providing a protective layer above the mineral soil. In some locations, the depth of the duff layer exceeded 10 centimeters. No evidence of sediment delivery to stream channels was observed. Site 6 is under the power lines near the headwaters of Jones Creek. Numerous off-road vehicle (ORV) tracks were observed which created significant ground disturbance and erosion. However, evidence of overland flow, and hence sediment delivery to stream channels from these sites with ground disturbance was not observed.

Vegetation cover in recently disturbed areas increases rapidly after disturbance. Of the 6 sites observed, the vegetation cover was not less than 20% of the plan view ground area. Climatic conditions west of the Cascades typically allow for rapid regrowth in clearcuts. Revegetation by herbs and shrubs covering 90% of the ground surface has been documented to occur within a few years of harvesting (Veldhuisen, 1994) in similar North Cascade terrain.

Erosion from agricultural lands within the South Fork Nooksack River floodplain is thought to be relatively low by agricultural standards (~0.5 - 1 tons/acre or 0.2 - 0.4 tonnes/ha), due to year-around plant cover (John Gillies, Whatcom County SCS, personal communication). Much of the sediment generated is not carried to the stream network however, due to limited overland flow and periodic removal of sediment accumulated in ditches. Erosion generated by grazing or other disturbances along small streams from agricultural areas probably consists of very fine particles (i.e. clays), because sands and silts will settle out in low-gradient ditches, and removed during cleaning. This very fine sediment is unlikely to accumulate in gravel channels, but will contribute to turbidity during transport. Even when accounting for cover and delivery influences, the quantity of sediment delivery from agricultural lands appears to be substantial, on the order of 2600 - 5200 tonnes annually (Appendix 4.1). A comparison among fine sediment sources and their effects toward public resources is discussed further in Section 4.5

Table 4-2 Field Inspection Sites and their Soil Attributes.

Delivery Site # (legal)	Soil Unit #	Hillslope Gradient (%)	Percent Surface Cover: mineral soil (%)	Percent Surface Cover: slash /duff (%)	Percent Surface Cover: vegetation (%)	Sediment
1 (T37NR5ES6)[n]	1	<1%	5	0	95	no
2 (T47NR5ES4)[y]	10	40-60%	10	60	30	no
3 (T38NR5ES33)[y]	12	40-60%	10	50	40	no[a]
4 (T37NR5ES7)[y]	4	40-70%	5	55	40	no[a]
5 (T38NR5ES15)[y]	13	20-30%	10	60	30	no[a]
6 (T37NR4ES14)[y]	14	45-75%	10	70	20	no[a]

[a] evidence of surface flow (i.e. rills, sheetwash, etc.)
[n] site not located in recent harvest unit
[y] site located in recent harvest unit

4.2.4 Conclusions and Hazard Ratings

The hillslope erosion analysis results suggest that current methods of timber harvesting have not produced significant sediment delivery to stream channels (not considering logging roads). Limited evidence of surface erosion was visible at 4 of the 6 sites visited, but delivery of sediment to stream channels had not occurred. However, no sites were located immediately adjacent to stream channels. Past research and analyses (Coho, 1994, Veldhuisen, 1994) have shown that overland delivery of sediment from soil disturbance is limited to relatively short distances (20-50 feet).

Therefore the areas with the highest potential to deliver fine sediment from surface erosion are those within 50 feet of streams. In previous Surface Erosion analyses, streamside areas were identified as High or Moderate hazard, due to the potential for resource impacts if extensive soil disturbance were to occur. However this approach was not used here because the probability of substantial sediment delivery appears remote. Recent logging practices have avoided significant soil disturbance in streamside areas, which reflects either a high level of effectiveness of standard rules and/or adequate awareness by operators.

The lack of substantial sediment delivery from surface erosion from forestry activities supports the assignment of a Low hazard rating throughout the WAU. The blanket application of the Low hazard rating should not be interpreted as downplaying the sensitivity of streamside areas, but instead relies on the ongoing caution during logging and other soil disturbing practices along streams. Because no areas were rated as High or Moderate hazard, no revised erosion hazard map is required.

4.2.5 Confidence in Work Product

Hillslope surface erosion was analyzed by perusal of recent aerial photos and six field inspection sites. The aerial photo reconnaissance would enable detection of large-scale erosion features such as skid trails. The field inspections provided for more detailed observations of surface erosion at each site. Obviously, significant error exists when observations from specific sites are extrapolated across the entire WAU. However, results from numerous previous surface erosion analyses on the western slope of the Cascades have been consistent with those in this analysis. Because of this consistency, the confidence in hillslope erosion conclusions is good.

4.3 ROAD SURFACE EROSION

4.3.1 Introduction to Roads and Sub-Watersheds

Road access to valley bottom areas originates from Highway 9 and various paved or gravel-surface rural roads (Figure 4-3). Upland areas are reached by numerous gravel logging spurs, which are the primary focus of this assessment. Access is provided by numerous unconnected spur systems, with the exception of southern Van Zandt Dike which contains the N-1000 road network. Most logging roads on private timberlands are gated to exclude recreational traffic. Undriveable "orphaned roads" (i.e. unused for 20 years or more) occur in various upland parts of the WAU, though the greatest concentrations are located in the Northwest sub-watershed, as defined below.

The WAU was divided into five sub-watersheds (Figure 4-3) to evaluate the impacts of road surface sediment input at a more local scale. The Lowland sub-watershed contains valley bottom terrain that is predominantly used for agriculture and other non-forestry land uses. Both the western and eastern upland areas were subdivided into northern and southern portions for analysis, entitled the Northwest (NW), Southwest (SW), Northeast (NE) and Southeast (SE) sub-watersheds. The northern sub-watersheds (NW and NE) are characterized by low road densities and sedimentary bedrock, while the southern sub-watersheds (SW and SE) contain more roads and primarily phyllite geology. Each sub-watershed combines areas drained by numerous small tributary streams.

4.3.2 Road Erosion and Delivery

Road surface erosion and delivery rates were estimated for individual roads based on road-specific attributes (Table 4-3), using factors specified in the manual (WFPB 1994). Occasional modifications from the manual were made to better reflect field observations, as documented in Appendix 4.2. The most notable modification was the use of road-specific tread and cutslope widths, rather than generic "reference road" specifications. A delivery percentage was developed for each road segment, based on the number of direct entry ditch points (Table 4-3), most identified in the field, with supplemental use of aerial photos or maps. Erosion from fillslope surfaces is normally not delivered to streams, except from directly above the culvert outfall. For roads with no delivery, recording road attributes was unnecessary.

Roads were classified into four traffic categories (Figure 4-4): Heavy use (hauling traffic >50% of the time), Moderate use (10-50%) Light use (0-10%), and Abandoned/Put-to-bed (undriveable roads with varying levels of drainage deconstruction). The Heavy use category applies only to Highway 9 and the Mosquito Lake Roads, which are paved and appear to produce minimal erosion. The entire lengths of Moderate use forest roads and most of the Light use roads were field checked during the analysis. Information on abandoned or recently put-to-bed roads was developed from a field sample and aerial photos. Undriveable roads which are revegetated (including "orphaned" roads) do not appear to contribute significant sediment (except by triggering road failures, as discussed in Section 3.5) and thus were not analyzed.

Because traffic rates play a large role in determining road sediment production (Reid and Dunne 1984), the discussion of results focuses on traffic categories. In the Acme WAU, most sediment originates from Moderate-use and Light-use roads (Figure 4-5). The Moderate-use category includes two roads: the N-1000 road in the SE

Table 4-3 Road surface erosion calculations for the Acme WAU. 8-6-96

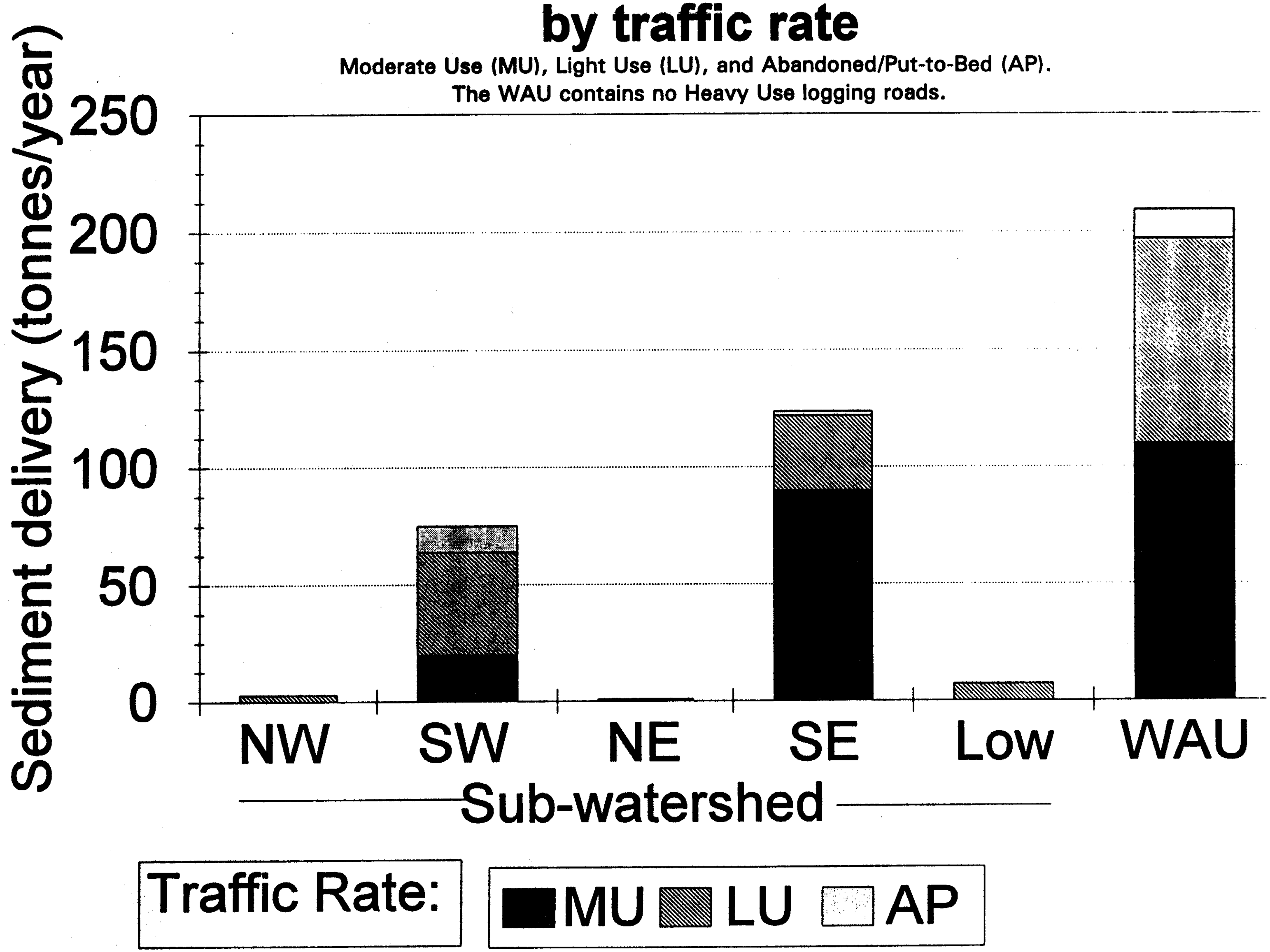
Road		–Delivery –		— Traffic —		—— Tread ——			- Cutslope -		- Direct entr		BER		-- Total sediment delivery (t/yr) --			
no & seg	lengt (mi)	Y/N	source	cat.	factor	srfce	width (ft)	orient	cover	heigh (ft)	length (mi)	%	tonnes/ ac/yr	Cmnts	Tread	Ctslop	Road total	Sub-wsh total
Northwest (NW) sub-watershed																		3
H-6000	1.8	Y	field	LU	1	0.2	16	0.5	0	15	0.05	3%	27		0.3	0.0	0	
6100	1.8	Y	field	LU	1	0.2	20	0.5	0.18	15	0.10	6%	27		0.7	0.9	2	
S 18	2.0	Y	map	LU-G	0.5	0.2	16	0.5	0.18	20	0.05	3%	27	0.05/Xing	0.1	0.6	1	
Upr. basin spurs		Y	photo	RV											0.0	0.0	0	
Southwest (SW) sub-watershed																		75
BPA	1.2	Y	field-K	MU-	2	1	12	1	0	10	0.25	21%	27	ORV use	19.6	0.0	20	
S 26	0.9	Y	field	LU-G	0.5	0.5	16	0.5	0.18	20	0.22	25%	27	brushed	1.4	2.6	4	
A-1000 a	0.7	Y	field	LU-G	0.5	0.2	16	0.5	0	0	0.26	37%	27		0.7	0.0	1	
A-1000 b	2.8	Y	field	LU-G	0.5	0.5	16	0.5	0.18	20	0.43	15%	27		2.8	5.1	8	
S 6	1.9	Y	photo	LU-G	0.5	0.2	16	0.5	0.18	20	0.05	3%	27		0.1	0.6	1	
1010	2.0	Y	field	LU-G	0.5	0.2	16	0.5	0.63	15	0.12	6%	55	new spur	0.6	7.6	8	
H-3000 a	2.0	Y	field	LU-G	0.5	0.2	16	0.5	0.18	10	0.40	20%	55	phyllite	2.1	4.8	7	
3000 B&D	0.4	Y	field	LU-G	0.5	0.2	16	0.5	0.77	20	0.02	5%	100	new spur	0.2	3.7	4	
3600	0.3	Y	photo	LU-G	0.5	0.2	16	0.5	0.18	10	0.20	80%	55		1.1	2.4	3	
3800 a	1.9	Y	photo	LU-G	0.5	0.2	16	0.5	0	10	0.33	17%	55		1.8	0.0	2	
3000 b	0.8	Y	field	LU-G	0.5	0.2	16	0.5	0	10	0.25	31%	55		1.3	0.0	1	
3300	1.4	Y	field-K	LU-G	0.5	0.2	16	0.5	0.18	20	0.35	25%	27		0.9	4.1	5	
3000 E-G	0.6	Y	photo	AP	0.05	0.2	16	1	0	10	0.08	13%	55		0.1	0.0	0	
3810	0.6	Y	photo	AP	0.05	0.5	16	1	0	10	0.10	17%	55		0.3	0.0	0	
3800 b	0.9	Y	map	AP	0.05	0.5	16	1	0.18	20	0.22	24%	100	new	1.1	9.6	11	
Upr. basin spurs		Y	photo	RV											0.0	0.0	0	

Road		--Delivery --		-- Traffic --		------ Tread ------			- Cutslope -		- Direct entry -							
no & seg	lengt (mi)	Y/N	source	cat.	factor	srfce	width (ft)	orient	cover	heigh (ft)	length (mi)	%	BER t/ac/yr	Commen	Tread	Ctslop	Road total	Sub-wsh total
Northeast (NE) sub-watershed																		1
Wms. Lk. access	0.4	Y	field	LU	1	0.5	12	0.5	0	0	0.10	24%	27		1.0	0.0	1	
S 33		N	field	AP											0.0	0.0	0	
S 4		N	field	AP											0.0	0.0	0	
Southeast (SE) sub-watershed																		91
1000a,b,d /1200	5.9	Y	field	MU-S	2	0.2	20	0.5	0.18	20	1.16	20%	55		30.9	27.8	59	
1500,A,B	0.8	Y	field	LU	1	0.2	16	0.5	0.18	15	0.10	13%	27	sndstone	0.5	0.9	1	
1000 c	0.9	Y	field	LU	1	0.2	16	0.5	0.18	10	0.48	52%	55		5.1	5.8	11	
1000 e	1.3	Y	map	LU	1	0.5	14	1	0.18	10	0.63	47%	27	sndstone	14.4	3.7	18	
1007	0.6	Y	map	LU-V	0.5	0.2	12	0.5	0	10	0.05	8%	55		0.2	0.0	0	
1008-12		N	map	LU											0.0	0.0	0	
S 9, S 4		N	map	LU-G											0.0	0.0	0	
1006,1400		N	field	AP														
S 28	1.5	Y	field	AP	0.05	0.5	16	1	0.18	15	0.07	5%	55		0.2	1.3	1	
1500 C		N	field	AP											0.0	0.0	0	
1001-4		N	map	AP											0.0	0.0	0	
Lowlands sub-watershed																		9
Hwy 9		N	field	HU		paved									0.0	0.0	0	
Paved rural		Y	field	MU		paved									0.0	0.0	0	
Grvl rural	5.4	Y	field	MU	1	0.2	20	1	0.18	5	0.54	10%	27		7.1	1.6	9	
WUA Total																		178

Note: Capitol letters identify distinct roads, while lower case indicate road segments

Figure 4-5 Road sediment inputs by traffic rate

Moderate Use (MU), Light Use (LU), and Abandoned/Put-to-Bed (AP).
The WAU contains no Heavy Use logging roads.



sub-watershed and the BPA road in the upper SW sub-watershed. The N-1000 is a primary logging road that is in good repair but generates tread erosion due to the contribution of frequent traffic. The BPA road is a power line access road that receives heavy recreational use during the wet season by off-road vehicles (Kip Kelley, DNR Forester, personal communication). Light-use roads comprise the greatest total road length in the WAU and sediment is generated from both tread and cutslope surfaces. Among all road types, cutslopes contain the greatest erodible surface area, though erosion is often reduced by partial vegetation cover. Among all roads, direct entry is generally low, in most cases less than 25% of the total road length. Roads recently put-to-bed produce minimal sediment contributions (Figure 4-5).

Among the four sub-watersheds, road sediment delivery rates from the NW and NE sub-watersheds appear to be very low (~1-3 tonnes/year, Figure 4-5), due to the limited extent of driveable roads. In the NW sub-watershed, most existing logging roads are revegetated orphaned roads that don't produce surface erosion. Road surface erosion is greater in the SW sub-watershed (~75 tonnes/year), largely due to the BPA road and contributions from numerous Light-use roads, many built within the past decade. Soil erodibility is also a factor, as most roads south of Jones Creek expose phyllite-derived soils which are naturally more erodible than the sedimentary-derived material prevalent to the north.

The SE sub-watershed contains the most extensive road network and not-surprisingly, the greatest road sediment delivery (~91 tonnes/year, Figure 4-5). The primary road (N-1000, mentioned above) produces 90% of the total sub-watershed sediment inputs, due largely to the moderate traffic level and the 2.3 miles of direct entry length over the eight-mile total.

Gravel roads in the Lowland sub-watershed, mostly rural access roads, produce modest amounts of sediment (~7 tonnes/year, Figure 4-5). Sediment from tread surfaces is washed into low-gradient (<1%) roadside ditches. Periodic removal of accumulated sediment, prevents transport of most road sediments (especially sand and silt-sized particles) to streams.

4.4 EFFECTS ON PUBLIC RESOURCES AND HAZARD RATINGS

The fine sediment (particles <2 mm in diameter) generated by surface erosion can impact public resources through two well-documented processes (Everest et al. 1987). First, fine sediment that is deposited on stream-beds can degrade spawning habitat of salmonid fish and have other effects to fish and other organisms. Second, when carried in suspension, fines can increase turbidity and thus degrade water quality for aquatic organisms, domestic consumption, or other uses. Because mountain streams naturally transport substantial sediment loads, the magnitude and timing of land use sediment inputs relative to natural sediment loads is considered the key to evaluating the degree of impact that is occurring (WFPB 1994).

The Surface Erosion module specifies two methods for estimating background sediment production: estimating soil creep inputs or estimating basin sediment yield by extrapolating from published data from a comparable watershed (WFPB 1994). Both approaches were employed for the Acme WAU (Appendix 4-3) though both estimates involve uncertainty and should be seen as approximate. Field observations suggests that many small streams do not appear on maps of the Acme WAU, thus reducing confidence in soil creep calculations (Appendix 4-3A), which are directly proportional to stream length. Despite attempts to adjust for this frequently-encountered problem, it is likely that soil creep input rates are underestimated, especially in the eastern sub-watersheds. In addition, little sediment yield data has been collected in North Cascades basins that would allow extrapolation (Appendix 4-3B). Due to these uncertainties in sediment quantification, other observational information was considered in evaluating the relative importance of land use sediment inputs, as discussed below.

NW, SW and NE sub-watersheds: Road surface inputs in the NW and NE sub-watersheds are minimal, and much smaller than the soil creep estimates for each sub-watershed (Table 4-4). Road inputs in the SW sub-watershed are larger, but still only 25% of the background. This supports a Low hazard rating for each of these sub-watersheds. Although the soil creep rate for the NE sub-watershed is probably underestimated, it would take a major change to alter the resulting rating. Field data was more useful in adjusting the stream lengths for the NW and SW sub-watersheds, so these soil creep rates may be reasonably close.

SE sub-watershed: Road surface inputs in the SE sub-watershed are substantial, being approximately 1.5 times the soil creep estimate (Table 4-4), which would suggest a High hazard rating. As discussed previously, the soil creep rate is probably underestimated, due to incomplete mapping of small streams in this area.

The potential impact of road sediment originating in the SE sub-watershed is enhanced because most is routed into Black Slough, which contains important rearing habitat (Section 8.0, Fish Habitat). Fine sediment levels in Tinling Creek (15% <0.85 mm) are considered only Moderate and there is little evidence of turbidity problems, however. During several field visits, road-side ditches and small streams below roads were running clear. Local managers have not noticed turbidity problems in Black Slough (which crosses under heavily-traveled Highway 9), though pool filling was mentioned as a possible problem (Section 8.0, Fish Habitat). The underestimation of soil creep input and lack of evidence of turbidity problems supports the decision that a Moderate rather than High hazard rating is most appropriate for road erosion in the SE sub-watershed. Sediment entering Black Slough from neighboring agricultural lands is probably of a comparable scale to road surface inputs.

The very low stream gradient and abundant vegetation in Black Slough make it highly retentive of fine sediment. However, sediment storage in the slough reduces

Table 4-4 Sediment delivery rates from road surface erosion, agricultural lands and soil creep for sub-watersheds in the Acme WAU.

Sub-watershed	Sb-w area km2	Road surfaces total tonnes	Road surfaces tonnes/ km2	Agric. lands 1 total tonnes	Agric. lands 1 tonnes/ km2	Soil creep 2 total tonnes	Soil creep 2 tonnes/ km2	RS/SC ratio 3	Road Hazard rating
Northwest	16.7	3	0.2	0	0.0	213	12.8	0.01	L
Southwest	22.1	75	3.4	0	0.0	299	13.5	0.25	L
Northeast	10.9	1	0.1	0	0.0	48	4.4	0.02	L
Southeast	13.0	91	7.0	0	0.0	60	4.6	1.52	M 4
Lowlands	20.2	9	0.4	410	20.3	0	0.0	—	L
WAU total	82.9	199	2.4	410	4.9	627	7.6	0.32	L

1 - Calculations used to estimate sediment input from agricultural areas provided in Appendix 4.1.
2 - Soil creep calculations provided in Appendix 4.3 A.
3 - Road surface input divided by soil creep input.
4 - Downrated to Moderate due to underestimation of soil creep rate.

downstream transport, and limits the potential impact to the South Fork and mainstem Nooksack.

Lowlands sub-watershed: The sediment contribution from gravel roads appears to be greatly exceeded by those from agricultural lands (Table 4-4). Estimating background sediment production is problematic in this sub-watershed, since soil creep would not occur in this virtually flat terrain. Still, the relatively small input from roads supports a hazard rating of Low. Although watershed analysis does not assign ratings to non-forestry impact, sediment inputs from agricultural input would probably be rated Moderate or High for this sub-watershed.

Entire Acme WAU: The effect of fine sediment from the WAU on fine sediment dynamics in the South Fork requires consideration of the context of sediment production from areas upstream of the WAU (discussed further in Chapter 7 Channels). Total sediment production from the entire South Fork basin is probably on the order of 100-150 tonnes/km2/year, based on sediment budget work in the upper South Fork basin (Jeff Kirtland, personal communication), and sediment yield data from comparable Cascade basins. As in other steep basins, landsliding is the dominant erosional process (Swanson et al. 1987, Kirtland, personal communication), and contributes the majority of fine sediment routed through the lower South Fork channel. Within the WAU, road surfaces, agricultural lands, and soil creep are estimated to contribute 2, 5, and 8 tonnes per square kilometer of drainage area, respectively (Table 4-4). The differences in scale of these numbers suggests that roads and perhaps even agriculture in the Acme WAU generate only a small proportion of the total sediment load. Because these inputs are small relative to the total sediment load in the South Fork, fine sediment produced in the WAU likely has a relatively greater impact within the local tributaries than downstream in the South Fork or mainstem Nooksack.

4.5 CONFIDENCE

Confidence in road erosion rates is good for those roads which were field checked, which includes most logging roads. Results for roads that were not field checked, including many in the Lowlands sub-watershed, is considered fair. Although relative differences between roads or sub-watersheds are probably credible, actual sediment production rates should be considered approximate, since the road erosion model has not been field validated.

Evaluating the role of fine sediment on aquatic resources is problematic, due to mapping limitations that affect the soil creep model. Confidence in hazard calls is good for sub-watersheds where there are gross differences between natural and management sources (i.e. NW or NE). In the SE sub-watershed, where roads and soil creep are similar in scale, refinements in either calculation could easily change the hazard call, so confidence is only considered fair.

And finally, despite the value of considering erosion processes at a watershed scale, these methodologies are generally incapable of identifying small-scale surface erosion problems. Preventing local impacts requires awareness and attention from landowners, contractors, and regulators, during the course of any soil disturbing activities.

4.6 REVIEWERS' DIRECTORY

The following list is provided to help reviewers locate each of the requested items listed on page B-34 of the Manual.

I. Watershed overview - *see Sections 4.2.2 for hillslope erosion processes and 4.3.1 for road erosion.*

II. Watershed partitioning - *see Section 4.3.1*

III. Hillslope surface erosion results
- Preliminary Surface Erosion Map - *Figure 4-1*
- Contributing Activities Map B-3 - *Figure 4-2*
- Forms B-1, Hillslope Field/Photo Information - *summarized in Section 4.2.3 and Table 4-2*
- Final Surface Erosion Potential Map B-4 - *no map was necessary - see Section 4.2.4*
- Narrative - *provided as Section 4.2.3*

IV. Road erosion results
- Form B-2, Road calculation spreadsheet - *Table 4-3*
- Forms B-3, road field forms - *Table 4-3.*
- Map B-6, Road Segment Delivery - *see Figure 4-4*
- Narrative *included in Section 4.3 Road Surface Erosion*

V. Surface Erosion Effects on public Resources
- Forms B-4, Surface erosion summary - *summary data is provided in Table 4-4, and illustrated in Figure 4-5*
- Narrative *provided as Section 4.4*

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APPENDIX 4-1

Appendix 4-1 Sediment delivery calculations for agricultural lands in the Acme WAU.

Acreage of Agricultural lands in Acme WAU: ~6,000 acres
Estimated from interpretation of orthophoto soil map in Whatcom County Soil Survey (Goldin 1992)

Erosion rate, agricultural lands in Acme WAU: 0.75 ton/acre/year
Midpoint of 0.5-1.0 ton/acre/year range provided by John Gillies.

Delivery rate: 10%
Estimated, based on drainage density (streams and ditches) in agricultural areas and sediment removal during ditch cleaning.

Total Sediment delivery rate:

6,000 ac. X 0.75 ton/ac/year X 0.10 (dlvry) = 450 tons/year
X 0.91 tonnes/ton = 410 tonnes/year

APPENDIX 4-2

Appendix 4-2 Considerations and deviations for road erosion calculations

I. Road analysis factors and rationale

Traffic rates: Traffic factors were based on the Moderate precipitation range (1200-3000 mm/year, Table 8, page B-26). Traffic factors reduced by 50% where the road is gated or has seasonal hauling restrictions (e.g. N-1000).

Segment conditions (tread, cutslope, etc.) are limited to direct entry segments and may not represent entire road.

Direct entry: Assumed that direct entry sites could be determined in the field. Direct entry inferred at channels or continuous gullies below outfall. For abandoned and unsurveyed roads, direct entry was based on the number of stream crossings determined from maps: Abandoned roads - 200' road length per crossing, Light-use roads - 400' per crossing.

Tread Orientation: Appeared "combination" suitable in most places, because roads are either crowned or contain alternating insloped and outsloped portions. Combination category assumes that 50% of tread sediment goes to ditch, while the other 50% drains onto the fill slope with no delivery.

Cutslope vegetation: In places, cutslopes are well covered with dense vegetation and do not appear to produce any appreciable erosion. An erosion factor of 0 was used rather than 0.18 (of the rate with no cover), as suggested for 80-100% cover (WFPB 1994).

Gravel roads in Lowland sub-watershed: Estimated 10% sediment delivery, to account for non-direct entry runoff and removal of sediment accumulated in ditches.

APPENDIX 4-3

Appendix 4-3 Background sediment production rates for the Acme WAU. 4-3-95
A. Soil creep calculations, B. Basin sediment yields.

A. Soil creep calculations

Sub-watershed	Area (km2)	Water type *	Stream length (m)	Soil depth (m)	Creep rate (m/yr)	Creep volume (m3)	Bulk dnsty (t/m3)	Creep mass (t)	Sub-WAU total (t)	(t/km2)
NW	16.7	3	490	1.0	0.002	2.0	1.5	3		
		4&5	26520	1.0	0.002	106.1	1.5	159		
		U	8530	1.0	0.002	34.1	1.5	51	213	12.8
SW	22.1	3	850	1.0	0.002	3.4	1.5	5		
		4&5	36570	1.0	0.002	146.3	1.5	219		
		U	12490	1.0	0.002	50.0	1.5	75	299	13.6
NE	10.9	3	1580	1.0	0.001	3.2	1.5	5		
		4&5	860	1.0	0.0015	2.6	1.5	4		
		U	6580	1.0	0.002	26.3	1.5	39	48	4.4
SE	13.0	4&5	10050	1.0	0.002	40.2	1.5	60	60	4.6
Lowlands	20.2	none						0	0	0
Total WAU	82.9								621	7.5

* - Water types indicated by DNR maps. U indicate untyped streams identified from USGS maps and/or field.

B. Basin sediment yields

Basin (author)	What was measured	Basin area km2	Annual yield t/km2
Upper So. Fk. Nooksack River (Kirtland 1995)	Total inputs	~ 150	126
Skykomish River (Larsen & Sidle 1980)	Suspended sediment yield *	2160	98
Snoqualmie River (Larsen & Sidle 1980)	Suspended sediment yield*	1562	134

* - Does not include bedload, which likely comprises 5-20% of the combined total.

APPENDIX 4-3

Supplemental Road Surface Erosion Analysis

An addendum to the Surface Erosion Assessment - Acme WAU
April 15, 1999
Curt Veldhuisen

Introduction

The Surface Erosion Assessment for the Acme WAU was completed in 1996 and underwent Technical Review in January 1997. During the final phase of prescription writing in March 1999, concerns were raised that the substantial lengths of new road construction and reconstruction since 1996 had not been evaluated in the original assessment. The potential issue was that prescriptions that resulted from assessment of the shorter 1996 road network might be insufficient to mitigate the effects of additional sediment inputs from these new roads, either individually or collectively.

To resolve this question, the prescription team requested a supplemental assessment of new roads in the portions of the WAU containing most new roads: the Northwest and Southwest sub-watersheds (Figure S4.1). Erosion conditions for roads evaluated in the 1996 assessment were not generally updated, except where traffic rates were known to have increased or roads were put-to-bed. Road networks in the Southeast, Northeast, and Lowlands sub-watersheds were not reanalyzed because new road construction has been minimal in these areas. Curt Veldhuisen, the analyst for the 1996 Surface Erosion Assessment, performed the supplemental work as well. The additional assessment followed Version 4.0 of the Watershed Analysis Manual. In addition there have been no substantial changes in the road surface erosion methodology since the previous analysis was done.

Results of additional road assessment

Additional field evaluation focused on recent additions to the road network (Figure S4.1), and involved characterizing road conditions that influence surface erosion rates. Approximately half of the total new road length was field checked during March 1999. Because some new roads were inaccessible due to snow, characteristics for these roads were estimated using FPA maps and discussion with engineers familiar with these roads.

The 10 miles of new roads in the Northwest sub-watershed was nearly twice the total road length present in 1996. The Southwest sub-watershed presently contains about seven miles of new roads and another four miles of pre-existing road with increased traffic rates. As a general rule, new roads were built to a high standard, with good quality surfacing rock, widespread effort to stabilize cutslopes via grass-seeding and/or rip-rap, and frequent culverts that direct most road runoff onto hillslopes rather than into streams. However, due to these roads' young age (0-2 years) and hauling traffic, predicted sediment production rates are fairly high. Table S4.1, an updated version of Table 4-3 from the original analysis, shows road characteristics and sediment production for each road individually.

Hazard Ratings

As in the original assessment, Hazard ratings were determined for each of the two sub-watersheds by comparing the updated road sediment production rate against background sediment input rates from the soil creep model. For the Northwest sub-watershed, the total road input of 14.2 tonnes/km^2/yr is equivalent to a 111% increase above background (Table S4.1), resulting in a High hazard rating. The road contribution within the Southwest sub-watershed (16.4 tonnes/km^2/yr) is 122% relative to background (Table S4.1), also resulting in a High hazard rating. Because a 100% increase represents the break-off between Moderate and High hazard ratings, both of these sub-watersheds are in the lower end of ranges that would be assigned a High rating.

The High hazard ratings for the Northwest and Southwest sub-watersheds result in "Prevent" Rule Calls for both. The single Surface Erosion Causal Mechanism Report generated from the original Acme assessment was edited (attached here) to reflect expanded Resource Sensitivities for the two sub-watersheds involved. Rather than rewriting the Surface Erosion Assessment report, this supplemental write-up will be attached to the final report as an addendum.

Estimated Road Sediment Production over the Next Ten Years

Trends in total sediment production from the road network can be roughly extrapolated into the next decade on the basis of landowner projections for new road construction. Because projections of proposed road construction do not allow calculations of sediment inputs from roads to be built, the potential effects are described in approximate terms.

Additional road construction activity is proposed over the next 1-2 years (see map); after that, new construction and hauling traffic is expected to decrease substantially (Dave Chamberlain, Crown Pacific engineer, personal communication). Given this trend, I would expect that the road erosion model would predict network sediment production for the Northwest and Southwest sub-watersheds to remain at similar to slightly higher levels compared to 1999 rates (i.e. values in Table S4.1). Sediment input rates would not be expected to increase dramatically during this time, because the new construction will be partially offset by the aging of roads built in 1997 and 98. Once roads reach two years of age, their sediment production rates decrease by 50% or more, due largely to the change in the Basic Erosion Rate used (Table B-5 in the WA Manual). If road construction and traffic rates drop as projected, network sediment input rates should be considerably lower by 2005, and most likely stabilize in the Moderate or Low hazard range. Network sediment inputs would reach Low levels if many of the presently active roads were abandoned.

Table S4.1 Updated road surface erosion calculations for the Northwest and Southwest sub-watersheds of the Acme WAU. Prepared in March 1999.

Road #	other name	road age	info. from:	total length	direct entry	---Tread--- traffic	factr.	surf.	wdth.	orient	gated	---- Cutslope ---- cover	factr.	hght.	BER	-- Total Sediment Yield -- tread	CS	FS	total
			1	(mi)	%	2			(ft)	3				(ft)	t/ac/yr	---- all are tonnes/year ---			
NORTHWEST SUB-WATERSHED																			
4500	DNR H-60	Old	field	1.80	0.03	LU	1	0.2	16	0.5	N	100%	0.00	15	27	0.3	0.0	0	0.3
4500	6100	Old	field	1.80	0.06	LU	1	0.2	20	0.5	N	80%	0.18	15	27	0.7	1.0	0	1.7
4520	old "S18"	Old	map	2.00	0.03	LU	0.5	0.2	16	0.5	Y	80%	0.18	20	27	0.2	0.7	0	0.9
Pre-96 total				5.60															2.8
4530	S. Todd	New	field	1.93	18%	MU	4	0.2	16	0.5	Y	60%	0.30	20	55	14.8	13.9	0	28.7
4000 A	E. Sulton	New	map	1.36	50%	MU	4	0.2	16	0.5	Y	40%	0.44	25	55	29.0	49.9	0	78.9
4013.5	NW passag	New	map	1.14	48%	MU	4	0.2	16	0.5	Y	40%	0.44	15	55	23.3	24.1	0	47.4
4017.5	Eclipse	New	map	2.15	13%	MU	4	0.2	16	0.5	Y	40%	0.44	15	55	11.9	12.3	0	24.2
4600 C	Hookup-U	New	field	2.40	10%	MU	4	0.2	16	0.5	Y	40%	0.44	15	55	10.2	10.6	0	20.8
4000 C	E. Sulton	New	AZ-1	0.78	44%	MU	4	0.2	16	0.5	Y	60%	0.44	20	55	14.6	20.1	0	34.8
New total				9.76															234.8
Northwest sub-watershed total																			**237.6**

Sub-watershed summary:

Area:	16.7 km2	Soil Creep:	12.8	t/km2/yr	increase over SC:	111%
		RSE	14.2	t/km2/yr		

SOUTHWEST SUB-WATERSHED:

4000 D	S 26	Old	field	0.90	25%	LU	0.5	0.2	16	0.5	Y	80%	0.18	20	27	0.6	2.7	0	3.2
4640	A-1000 b	Old	field	2.80	15%	LU	0.5	0.2	16	0.5	Y	80%	0.18	20	27	1.1	4.9	0	6.0
H-3000 a		Old	field	2.00	20%	LU	0.5	0.2	16	0.5	Y	80%	0.18	10	55	2.1	4.8	0	6.9
3000 B&D		Old	field	0.40	5%	LU	0.5	0.2	16	0.5	Y	10%	0.77	20	55	0.1	2.1	0	2.2
3600		Old	field	0.30	80%	LU	0.5	0.2	16	0.5	Y	80%	0.18	10	55	1.3	2.9	0	4.2
3800 a		Old	field	1.90	17%	LU	0.5	0.2	16	0.5	Y	100%	0	10	55	1.7	0.0	0	1.7
3000 b		Old	field	0.80	31%	LU	0.5	0.2	16	0.5	Y	100%	0	10	55	1.3	0.0	0	1.3
3300		Old	field	1.40	25%	LU	0.5	0.2	16	0.5	Y	80%	0.18	20	27	0.9	4.1	0	5.0
3000 E-G		Old	field	0.60	13%	PTB	0.05	0.2	16	0.5	Y	100%	0	10	55	0.0	0.0	0	0.0
3810		Old	field	0.60	17%	PTB	0.05	0.2	16	0.5	Y	100%	0	10	55	0.1	0.0	0	0.1
3800 b		Old	field	0.90	24%	PTB	0.05	0.2	16	0.5	Y	80%	0.18	20	55	0.1	5.2	0	5.3

Table S4.1 (continued) **Updated road surface erosion calculations for the Northwest and Southwest sub-watersheds of the Acme WAU. Prepared in March 1999.**

		road	info.	total	direct	------------------Tread------------------						---- Cutslope ----				-- Total Sediment Yield --			
Road #	other name	age	from:	length	entry	traffic	fctr.	surf.	wdth.	orient	gated	cover	fctr.	hght.	BER	tread	CS	FS	total
			1	(mi)	%	2			(ft)	3				(ft)	t/ac/yr	---- all are tonnes/year ---			
Southwest sub-watershed (continued)																			
4600 A	A-1000 a	Updtd.	field	0.70	37%	MU	4	0.2	16	0.5	Y	100%	0	0	27	5.4	0.0	0	5.4
4600 B	1010	Updtd.	field	1.45	32%	MU	4	0.2	16	0.5	Y	80%	0.18	10	55	19.8	5.6	0	25.4
4630 A	L Spar tree	Updtd.	field	0.30	53%	MU	4	0.2	16	0.5	Y	80%	0.18	10	27	3.3	0.9	0	4.3
4610 A	old "S6"	Updtd.	field	1.82	32%	MU	4	0.2	16	0.5	Y	80%	0.18	15	41	18.5	7.8	0	26.3
BPA	power line	Updtd.	KK-1	0.70	21%	LU	0.5	0.2	16	0.5	Y	80%	0.37	10	27	0.4	1.8	0	2.2
BPA	power line	Updtd.	KK-1	0.50	21%	PTB	0.05	0.2	16	0.5	PTB	80%	0.37	10	27	0.0	1.3	0	1.3
3000 B&D	spurs	Updtd.	KK-1	0.40	5%	PTB	0.05	0.2	16	0.5	PTB	80%	0.18	20	27	0.0	0.2	0	0.2
Pre-96 total				18.47															**101.1**
4630 B	Spar Tree	New	field	1.38	64%	MU	4	0.2	16	0.5	Y	60%	0.3	20	55	37.7	35.3	2.97	76.0
4610 B	SMC upper	New	field	0.63	50%	MU	4	0.2	16	0.5	Y	50%	0.37	20	55	13.4	15.5	0	29.0
4615/16	Jones Ck.	New	field	1.17	29%	MU	4	0.2	16	0.5	Y	50%	0.37	15	110	29.0	25.1	0	54.1
4616 end		New	field	0.30	25%	MU	4	0.2	16	0.5	Y	30%	0.53	20	55	3.2	5.3	0	8.5
4610 spur	SMC lower	New	field	0.27	53%	PTB	0.05	0.2	16	0.5	PTB	50%	0.37	15	55	0.1	5.3	0	5.4
4060	Upper Jon	New	map	2.87	39%	MU	4	0.2	16	0.5	Y	50%	0.37	15	55	47.8	41.4	0	89.2
New total				6.62															**262.0**
Southwest sub-watershed total																			**363.2**

Sub-watershed summary:

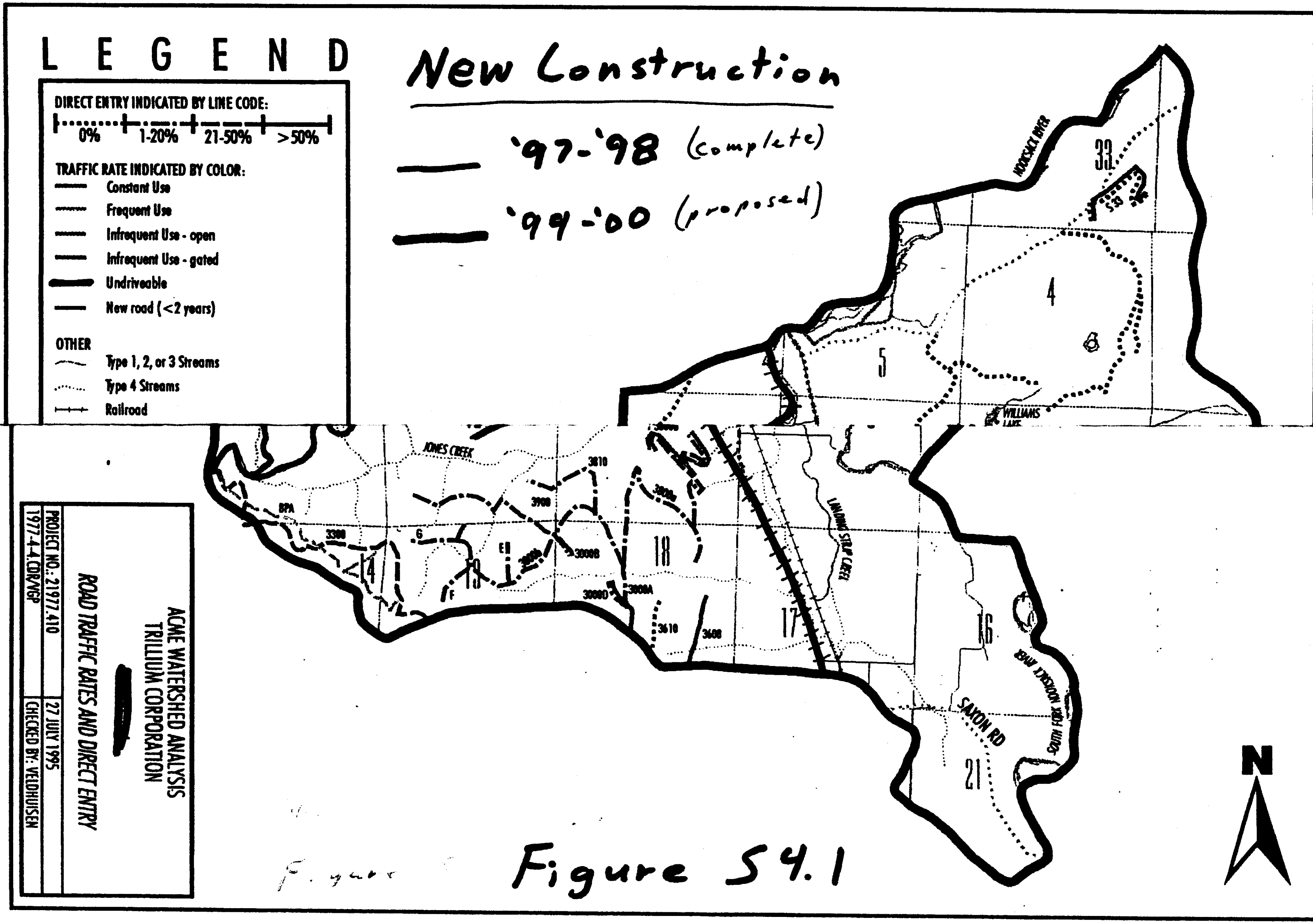
Area:	22.1 km2	RSE	16.4 t/km2/yr	increase over SC:	122%
		Soil Creep:	13.5 t/km2/yr		

Notes:

1 - Info from: AZ = Al Zander - hydrology consultant, KK = Kip Kelly - DNR forester

2 - Traffic categories: MU = moderate use, LU = light use, PTB = put-to-bed

3 - Orientation of the tread. All roads are crowned or shaped so that 50% of the surface drains toward the ditch.



LEGEND
DIRECT ENTRY INDICATED BY LINE CODE:
0%
1-20%
21-50%
>50%
TRAFFIC RATE INDICATED BY COLOR:
Constant Use
Frequent Use
Infrequent Use - open
Infrequent Use - gated
Undriveable
New road (<2 years)
OTHER
Type 1, 2, or 3 Streams
Type 4 Streams
Railroad
New Construction
'97-'98 (complete)
'99-'00 (proposed)
NOOKSACK RIVER
33
4
5
WILLIAMS LAKE
JONES CREEK
LANDING STRIP CREEK
SOUTH FORK NOOKSACK RIVER
SAXON RD
14
13
18
17
16
21
3810
3900
3000B
3000A
3000D
3610
3608
3300
N
ACME WATERSHED ANALYSIS
TRILLIUM CORPORATION
[redacted]
ROAD TRAFFIC RATES AND DIRECT ENTRY
PROJECT NO.: 21977.410
27 JULY 1995
1977-4-4.CDR/VGP
CHECKED BY: VELDHUISEN

Figure S4.1

CAUSAL MECHANISM AND PRESCRIPTION REPORT
Acme WAU
Report #4

Updated version (new in **bold**): C. Veldhuisen: 3-30-99

Resource Sensitivity:	ARS SE-1
Input Variables:	Fine sediment from road surface erosion
Hazard:	Moderate and High
Vulnerability:	High (Fish habitat)
Rule Call:	Prevent

Situation Statement:

The N-1000 and other gravel roads in the Southeast sub-watershed produce substantial fine sediment, most of which is routed toward the Black Slough. **Similarly, the many newly constructed roads in the Northwest and Southwest sub-watersheds contribute fine sediment to western tributaries (e.g. McCarty, Standard, Hardscrabble and Todd Creeks) and the South Fork Nooksack.** Fine sediments (<0.85 mm) have the potential to degrade spawning and rearing habitat by decreasing the depth and volume of rearing habitat and reducing spawning gravel suitability. Suspended sediment can also affect fish when delivered in sufficient quantity and duration.

Triggering Mechanism(s):

SE Sub-watershed: Although many roads contribute, most sediment appears to originate from the primary haul road: N-1000. Most sediment is generated from the road surfaces due to hauling wear.

NW and SW Sub-watersheds: Most sediment is contributed from various recently-constructed (i.e. 1998 & 99) roads. Although much of the sediment is generated from the tread in response to hauling traffic, additional amounts come from recently exposed cutslopes.

Prescriptions:

Same as previous, except where modified in the prescription meeting

Technical rationale:

SE Sub-watershed: *Use text from old CMR.*

NW and SW Sub-watersheds: A substantial number of new forest roads were constructed in 1997 & '98. Roads were generally built to high

standards in terms of tread surfacing, drainage design that minimizes ditch entry to streams and efforts to revegetate cutslopes via grass-seeding. Still erosion research suggests that sediment production rates are elevated over the first two years following construction, until exposed soils become armored. Because there are many new roads undergoing this "seasoning" process, the total sediment contribution slightly exceeds the background rate of sediment from soil creep, indicating potential turbidity impacts.

Several additional segments of road construction are projected for 1999 and 2000 to reach currently inaccessible parts of the WAU. Once these roads are completed, road construction rates are expected to drop off sharply. Total road sediment inputs should drop considerably as the many roads built between 1997-2000 pass the two-year age mark when the basic erosion rates drop to one-half the rate for 0-2 year-old roads. Depending on the future condition of the road network (traffic, revegetation, abandonment, etc.) at that time, total road sediment inputs are projected to stabilize at levels associated with Low or Moderate hazard ratings.

Technical Note:

Keep existing text, then add: Of the fine sediment produced from roads in the Northwest and Southwest sub-watersheds, greater proportions are expected to reach the South Fork, due to steeper tributary gradients (compared to Black Slough) which allow more efficient transport. Still the contribution to the overall fine sediment load in the South Fork is relatively small, once compared to the large fine sediment volumes originating in the upper basin. However, the potential for sedimentation impacts in the relatively steep western tributaries is lower, compared to the Black Slough.